

TNO report

**ThermoGIS V1.2
User manual**

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1 Disclaimer

The terms of this disclaimer apply to the ThermoGIS-website and its application of the Netherlands Organization for Applied Scientific Research TNO. This disclaimer is summarized here. By using the application you agree with the *complete* disclaimer, which can be downloaded from the TNO-website (www.tno.nl).

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2 Download and installation ThermoGIS

For a proper visualization, a screen resolution of at least 1280 x 1024 pixels is recommended.

To launch the Thermogis application *Java 1.6 or newer* should be installed. A free download is available via: <http://www.java.com>

To download ThermoGIS_expert click on '[ThermoGISv1.2 Expert application](#)' from the ThermoGIS homepage (Figure 1). Save and unpack the *ThermoGISExpert.zip* file in your preferred destination. Start the ThermoGIS_expert application by running the *ThermoGISExpert_v1_2.exe* file.



Figure 1. ThermoGIS expert can be downloaded from the website by clicking on the hyperlink expert application.

A disclaimer and messages window will appear before the ThermoGIS application launches (Figure 2). When you accept the disclaimer, click to continue. ThermoGIS_expert application will start up confirmation (Figure 3).

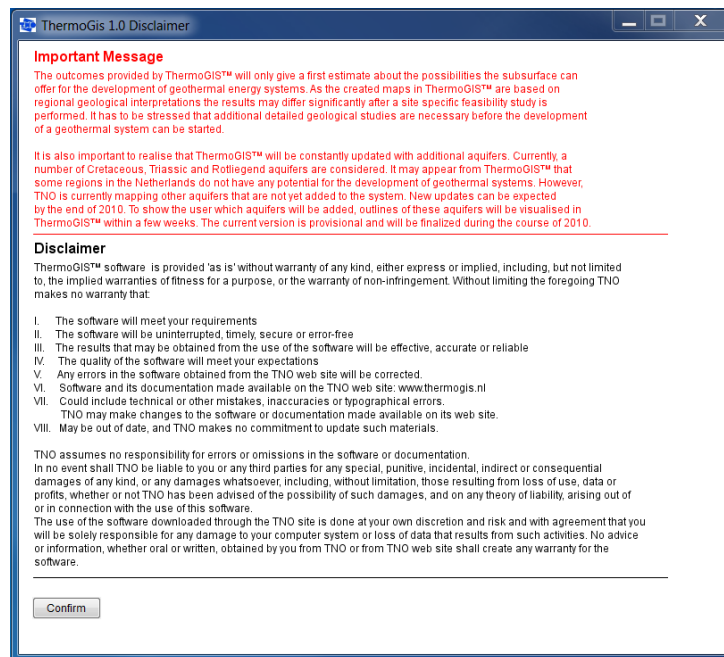


Figure 2 Important message and disclaimer window.

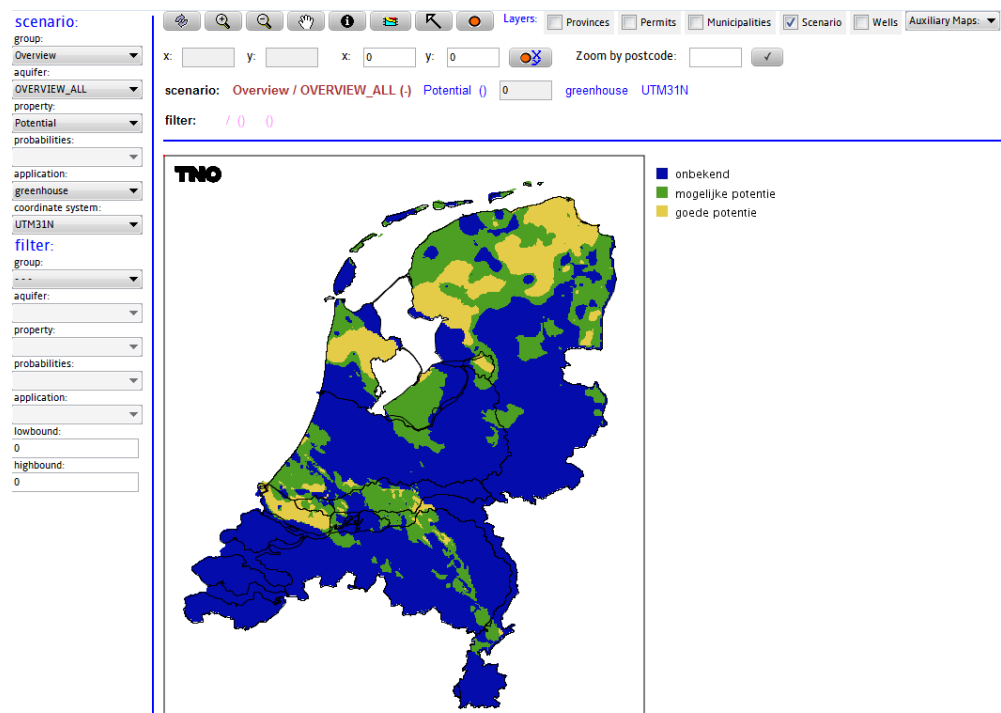



Figure 3. Opening screen of the ThermoGIS_expert application.

3 Getting started

In this chapter you will be introduced to the different panels, buttons, check- and combo boxes in ThermoGIS. In ThermoGIS a large variety of maps can be displayed. On the ThermoGIS website you may download several publications in which the methodology and assumptions are discussed in more detail.

Important note

Please note that after each selection from the combo boxes you have to click on the  button to retrieve the data. The data will not load automatically!

Retrieving the data may take some time as the data has to be downloaded from the server. The retrieving process is indicated in the top view of the window.

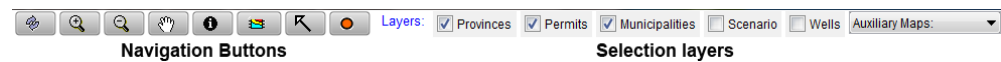


3.1 Panels in ThermoGIS

The application window comprises 8 different panels (Figure 4):









1) Toolbar

The toolbar at the top of the opening screen contains a button panel and layer checkboxes;



The functionalities of the navigation buttons are explained in Table 1.

Table 1 Description of the toolbox navigation buttons.

No.	Button	Description
1		Back to the initial openings screen
2		Zoom in
3		Restore previous magnification (zoom out)
4		Grasp and move map
5		Map parsing mode
6		Draw geologic cross section trace
7		Visualize the currently selected subsurface information
8		Set location point based on mouse input

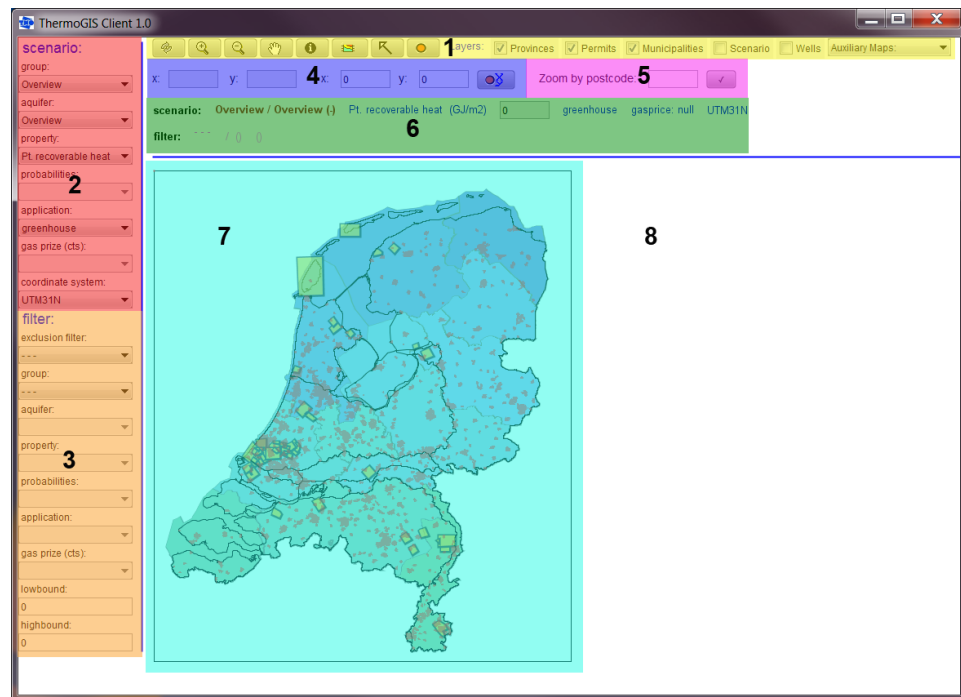


Figure 4 The ThermoGIS opening screen consists of 8 panels: 1) Toolbar, 2) Scenario selection combo boxes 3) Filter selection combo boxes, 4) Coordinate text boxes, 5) Postcode entering panel, 6) Information bar, 7) Display, 8) Legend area. A legend will appear to the right of the display after a scenario map is loaded.

2) Scenario combo boxes

On the left side of the application screen there is a panel of different combo boxes. In total six combo boxes can be distinguished. More information is given in 3.2.3 and 3.2.4.

For the methodology and assumptions used to create the maps see the publications on the website.

scenario:

group: Overview

aquifer: OVERVIEW_ALL

property: Potential

probabilities:

application: greenhouse

coordinate system: UTM31N

3) Filter combo boxes

By defining a lower and/or upper boundary in the filter combo boxes areas can be highlighted. For more detail see section 3.2.10.

filter:

group: ---

aquifer:

property:


probabilities:

application:

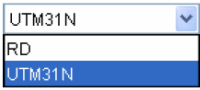
lowbound: 0

highbound: 0

4) Coordinate text boxes

From the x: y: text boxes the user can read out the x,y-coordinates of the cursor on the map display. Next to these text boxes the user can also enter X, Y coordinates x: y: himself. After the user press the  -button a location point will be plotted on the designated coordinates in the display panel. The default coordinate system is UTM31N.

To change from UTM31N to RD select the preferred coordinate system in the corresponding

combo box .

5) Postcode

The user may enter the postcode in the Zoom by postcode: text box. Press .

6) Information bar/title bar

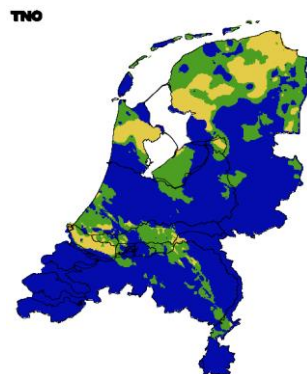
The information bar contains two sections:

- Title bar showing the selections made in the scenario selection combo-boxes
scenario: **KN / KNWNB (Rijnland Group)** Pt. recoverable heat (GJ/m2) greenhouse gasprice: null UTM31N
- Title bar showing the selections made in the filter selection combo-boxes
filter: gas fields KN / KNWNB (Rijnland Group) Pt. recoverable heat (GJ/m2) greenhouse 50 100

The information bar summarizes the selected and *activated* scenario and filter maps. This bar also provides information about the classes shown in the legend.

7) Display

In the display all retrieved data and the background layers are visualized.



8) Legend

Depending on the retrieved data the legend will show the colors and corresponding values.

- onbekend
- mogelijke potentie
- goede potentie

3.2 Introduction ThermoGIS-functionalities

In the following paragraphs ThermoGIS program will be discussed. To get more acquainted with application you may consecutively follow the explanations in the paragraphs below.

3.2.1 Layers [Layers: ☒ Provinces ☒ Permits ☒ Municipalities ☐ Scenario ☐ Wells]

The user interface allows showing a number of layers, which can be ticked on or off by using the layer-check boxes.

The five main layers are:

Layers: ☒ Provinces ☒ Permits ☒ Municipalities ☐ Scenario ☐ Wells

1. *Provinces*: displays the borders of the provinces in the Netherlands
2. *Permits*: displays a map containing geothermal licenses currently applied for
3. *Municipalities*: displays the municipalities of the Netherlands
5. *Scenario*: displays the selected parameter of the selected aquifer
6. *Wells*: displays the wells intersecting the selected aquifer

For example, switch on the provinces and municipalities, by ticking the corresponding check boxes. The background layer will be visualized in the display automatically (Figure 5).

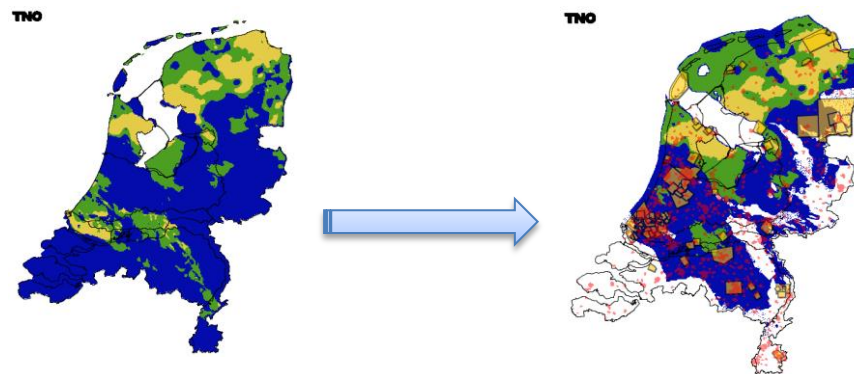


Figure 5 Updated map in the display when municipalities and provinces are ticked off.

3.2.2 Auxiliary maps [Auxiliary Maps: ▼]

Next to the layer check boxes some additional layers can be displayed. In the Auxiliary Maps combo box the following maps are selectable:

1. *2D seismic*: displays all 2D digital seismic lines
2. *3D seismic*: displays all 3D digital seismic lines
3. *Fields*: displays gas (green) and oil (red) fields

3.2.3

Scenario layers [group: Overview , aquifer: OVERVIEW_ALL , application: greenhouse , ☐ Scenario ,
 property: Potential]

To display a property map the ☐ Scenario should be checked first (is ticked on in default mode):

Layers: ☐ Provinces ☐ Permits ☐ Municipalities ☒ Scenario ☐ Wells

In the default mode no specific geological group or member is selected. This is indicated by

the combo boxes group: Overview and aquifer: OVERVIEW_ALL. Note that the check box of ☐ Scenario is tick on. If not checked, please tick on ☒ Scenario and the geothermal potential map will be displayed automatically.

Please note that there are two different sets of property maps available. The property maps 'potential', 'power indication', 'power application', 'Pt. recoverable Heat', 'Heat in Place' depend on the chosen application type (greenhouse or spatial heating). The difference between greenhouse and spatial heating is related to different assumptions and technical requirements.

In default the maps of application type 'greenhouse' are loaded. From the property combo box five different scenario layers can be selected. To view the geothermal potential for spatial heating, like residential areas, go to the application combo box (application: greenhouse) and choose spatial heating.

The overview mode shows data for ALL aquifers. All relevant geological data of each individual aquifers is compiled into one specific scenario map. These maps are also available in ThermoGIS_Basic.

In the overview mode five maps can be retrieved from the property box;

1. Potential (default);

The Potential map shows areas of good potential (yellow), possible potential (green) and uncertain/unknown (blue). This last category implies that no suitable aquifers are present aquifers are not mapped (yet) in this area.

2. Power indication

The power indication map shows the amount of recoverable heat power per doublet:

- Unknown (no data, no aquifer present)
- Moderate potential > 10 MW_{th}
- Good potential > 10 MW_{th}
- Good potential > 15 MW_{th}
- Good potential > 20 MW_{th}

3. Power application

The power application map indicates the number of houses or hectare of greenhouse that can be heated by one single doublet.

4. Pt. Recoverable Heat. This is the heat which can be recovered from the reservoir, unconstrained by techno-economic limitations, irrespective of flow properties
5. Heat in Place; Heat in place is the maximum theoretically extractable heat of all mapped aquifers

See for more detail information about the assumptions and methodology used the publications which are downloadable from the website.

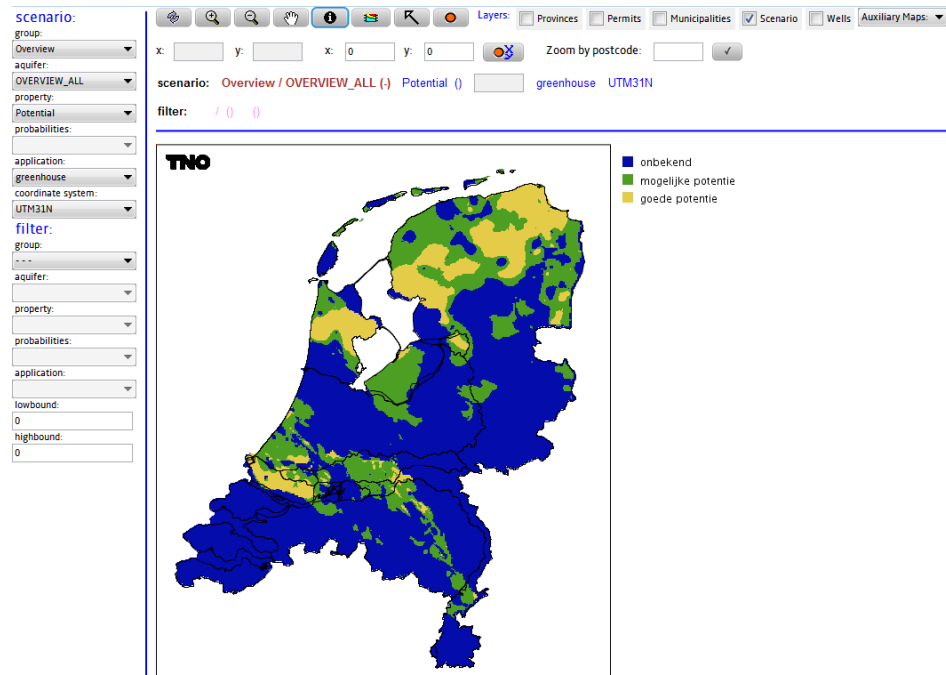


Figure 6. In the opening screen the Potential Recoverable Heat (GJ/m^2) is displayed. This map is compiled from all mapped aquifers. Note that there is no specific geological data available in overview mode.

3.2.4 Load aquifer property maps [scenario: Overview, aquifer: RO_STACKED, i]

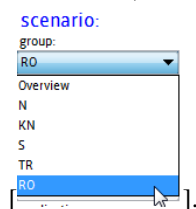
Please note that only the most promising aquifers are mapped so far in ThermoGIS. More aquifers may become available in the future.

Occasionally, new well data becomes available. Especially in areas with low data density (few wells) new well data may give more detailed information on the reservoir properties of an aquifer. This will affect the values shown in ThermoGIS. TNO strives to update ThermoGIS on a yearly base to add the new data into the geological maps.

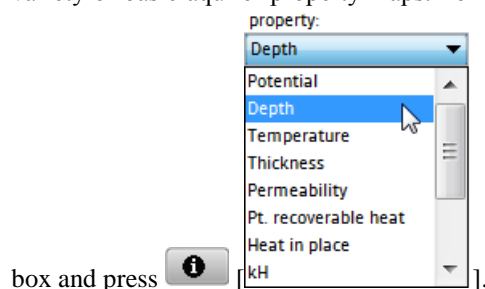
To display the data for a specific geological group and its corresponding members (aquifers) the combo boxes in the **scenario:** panel should be operated. In Table 2 the names of the stratigraphic groups and members and their codes are listed.

Selection starts by choosing a geological group from the **group:** Overview combo box. Notice that the aquifer and property combo boxes change automatically.

For instance, select the geological group RO (Upper Rotliegend) in the **scenario:**-panel




The combo box **property:** **Potential** will list all the aquifers that belong to the RO-group. Also the property combo box will be reloaded automatically. This enables the user to choose a variety of basic aquifer property maps. For instance, select 'depth' from the **property:** combo




The depth map will be retrieved from the server (Figure 7).

Table 2 List of mapped geological units and the ThermoGIS group/member codes.

Stratigraphic unit	Stratigraphic Group	ThermoGIS group code	Stratigraphic Formation	Stratigraphic Member	ThermoGIS member code
North Sea	Lower North Sea	N	Veldhoven	Voort	NMVV
				Steensel	NMRFT
				Vessem	NMRV
			Dongen	Basal Dongen Sand	NLFFD
				Reusel	NLLFR
			Landen	Heers Sand	NLLFS
				Swalmen	NLLFL
				Swalmen, Heers Sand, Reusel, Basal Dongen Sand, Vessem, Steensel, Voort	N-Stacked
Lower Cretaceous	Rijnland	KN	Vlieland Sst.	Friesland Sst.	KNNSF
				Gildehaus Sst.	KNNSG
				Bentheim Sst.	KNNSP
				Rijswijk Sst., Berkel Sst., IJsselmonde Sst., De Lier Sst. stacked	KNWNB
Jurassic	Schieland	S	Nieuwerkerk	Delft Sst.	SLDND
				Jurassic & Lower Cretaceous	JK-Stacked
Triassic	Upper Germanic Triassic	TR	Röt	Röt Fringe Sst.	RNROF
	Lower Germanic Triassic		Hardegsen		RBMH
			Detfurth	Upper Detfurth Sst.	RBMDU
				Lower Detfurth Sst.	RBMDL
			Volpriehausen	Upper Volpriehausen Sst.	RBMVU
				Lower Volpriehausen Sst.	RBML
Permian	Upper Rotliegend	RO	Slochteren	Lower Volpriehausen Sst., Upper Volpriehausen Sst., Lower Detfurth Sst., Upper Detfurth Sst., Hardegsen Fm., Röt Fringe Sst.	TR-Stacked
				(Upper) Slochteren	ROSLU & ROSL
				Lower Slochteren	ROSL
				(Upper) Slochteren and Lower Slochteren	RO-Stacked

ThermoGIS offers a number of maps which can be selected from the scenario or filter combo boxes. After making a new selection the user has to retrieve the new data by pressing . In the previous paragraph a depth map of the RO_stacked was loaded. To display for instance a permeability map, the user has to proceed as follows:

First select '*Permeability*' in the property combo box and click on  to retrieve the data (Figure 8). The display will then refreshed showing the permeability map.

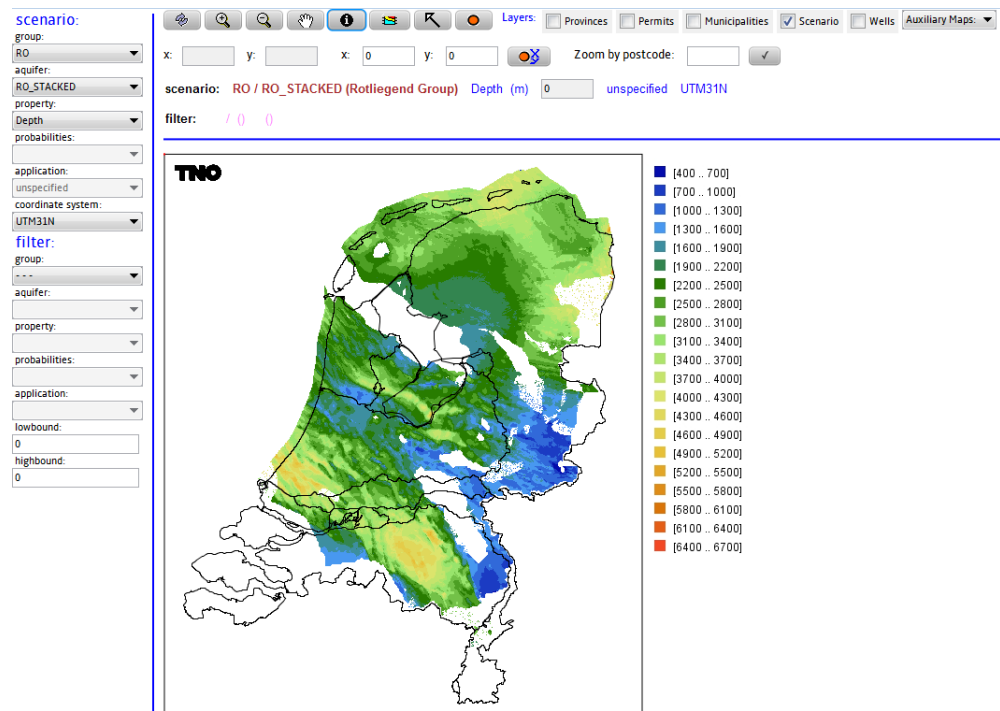


Figure 7 The depth map of the RO aquifers is displayed after the RO, RO_stacked and depth are selected from respectively the group, aquifer and property combo boxes.

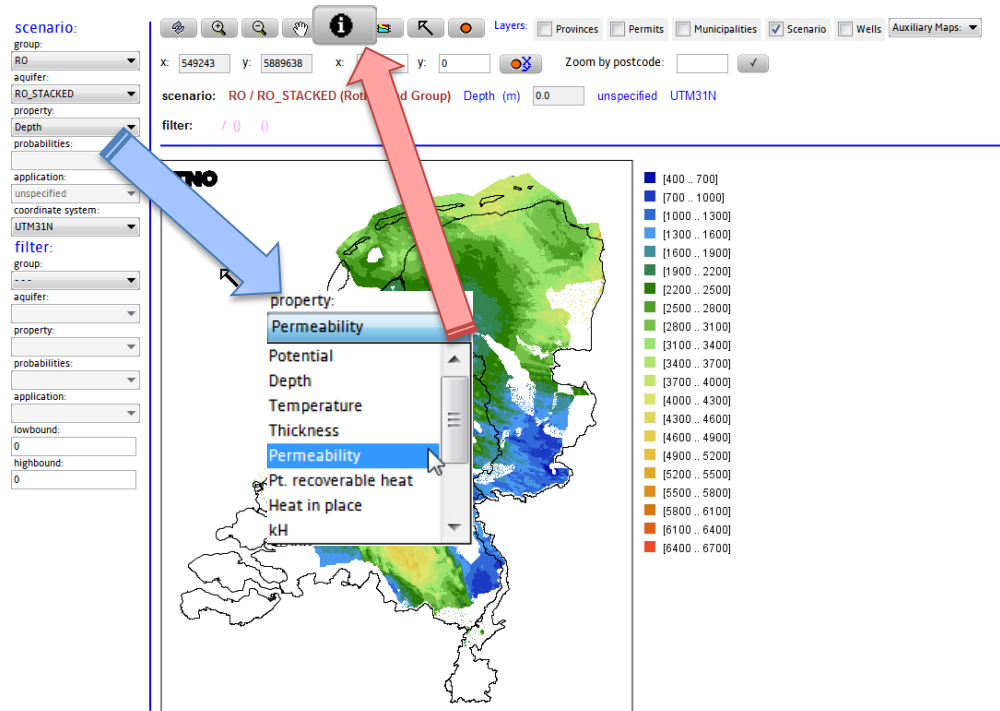






Figure 8 Change from the depth map to permeability map of the loaded RO_Stacked aquifer map.

3.2.4.1 Probability transmissivity

When you have loaded a transmissivity map (kH) you may select different probability maps from the menu. P90, P70, P50, P30 en P10 maps show the probability that the displayed transmissivity will actually will be observed.

3.2.5 Zooming into an area [, ,]

When the user presses the  button, ThermoGIS will switch to the Zoom-in mode. The cursor changes to the  - pictogram. An area can be magnified by keeping the left mouse button pressed and subsequently drawing a rectangle on the map (Figure 9). After releasing the mouse button the display zooms in to the selected area (Figure 10). To go back to the previous magnification use the  button.

In the grasp-mode you may  grasp and move the map in any direction. To grasp the map press and hold the right mouse button.

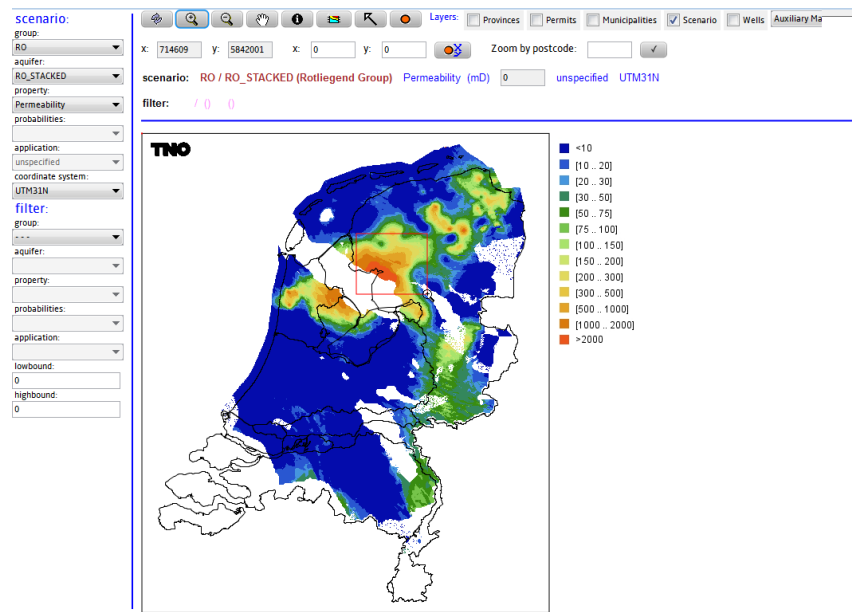


Figure 9. Zoom in to the selected area after the 'zoom in' mode is activated.

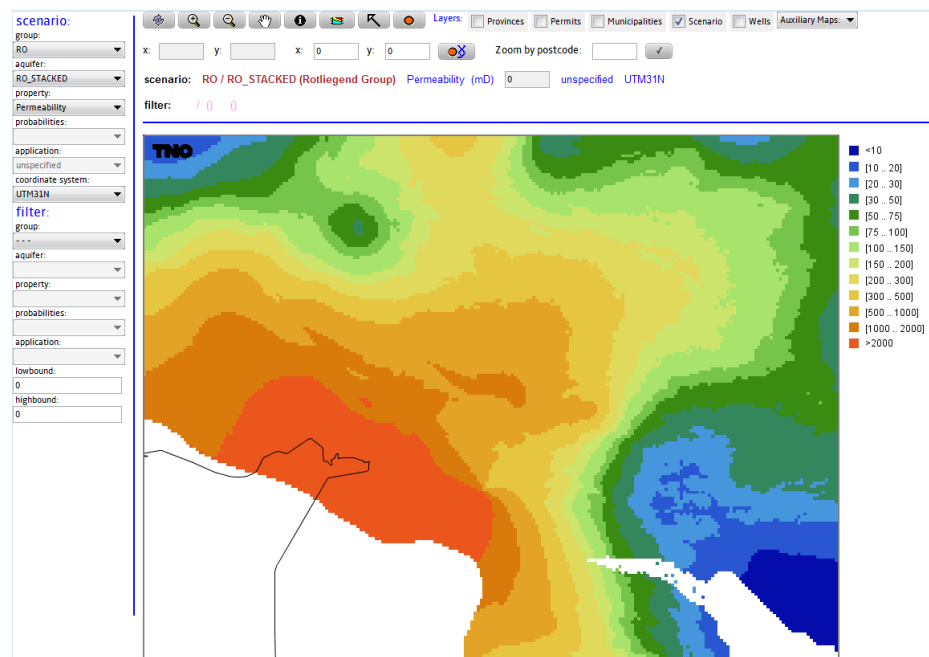



Figure 10 The selected area shown in Figure 9 is enlarged automatically after the zoom-in button is released.

3.2.6 Displaying wells ☐ Wells]

When the checkbox 'wells' (☐ Wells) is marked a layer will be displayed showing all onshore well locations and their well code. In default mode all wells are colored red. In case the user has selected any of the following property maps, viz.

Temperature Thickness Permeability kH

wells will turn into a different colors after the data is retrieved (Figure 11). Make sure that you press  again when a new group/aquifer or property map is selected from the combo boxes. The color indications informs the user when data is available and if it is used for the property modeling of the selected property. Four colors can be distinguished as demonstrated below;

- ♦ AKM-02 Red → no data available,
- ♦ OPH-01 Green → property data is used,
- ♦ SNK-02 Orange → data available but not used and,
- ♦ SHV-01 Magenta → data available but rejected after quality check.

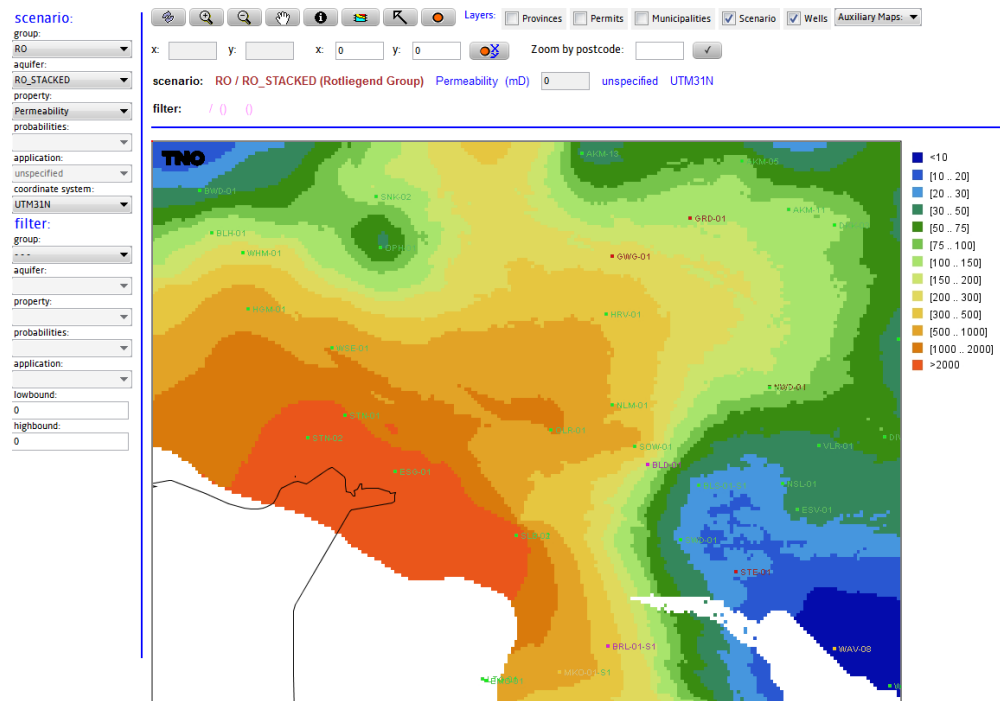




Figure 11 after ☐ Wells is ticked all wells that penetrate the selected aquifer (in this case RO_stacked) will be displayed. Note the different colors. Green colors correspond to wells that are used to map the property temperature, thickness, permeability or kH.

3.2.7 Draw geologic cross section trace []

By clicking on  the cross section-mode is activated. This is indicated by the cursor . A cross section trace can be drawn on the display while keeping the left mouse button pressed (Figure 12). After releasing the mouse button a new window will pop up which will show a geologic cross section (Figure 13).

When moving the cursor across on the cross section-window the coordinates will appear in an info tag alongside the cursor displaying the x, y coordinates and depth (z), for instance:

x: 582339
y: 5750728
z: -0.67 km

The cross section displays the structural geology of the subsurface. On the main display window a green circle appears that indicates the location of the cursor on the cross section window.

In the cross section the selected aquifer is highlighted in purple. A legend on the right side of the display informs the user about the other colors and corresponding geological groups (Figure 13).

Make sure that the cross section window is closed before a new cross section is drawn on the display.

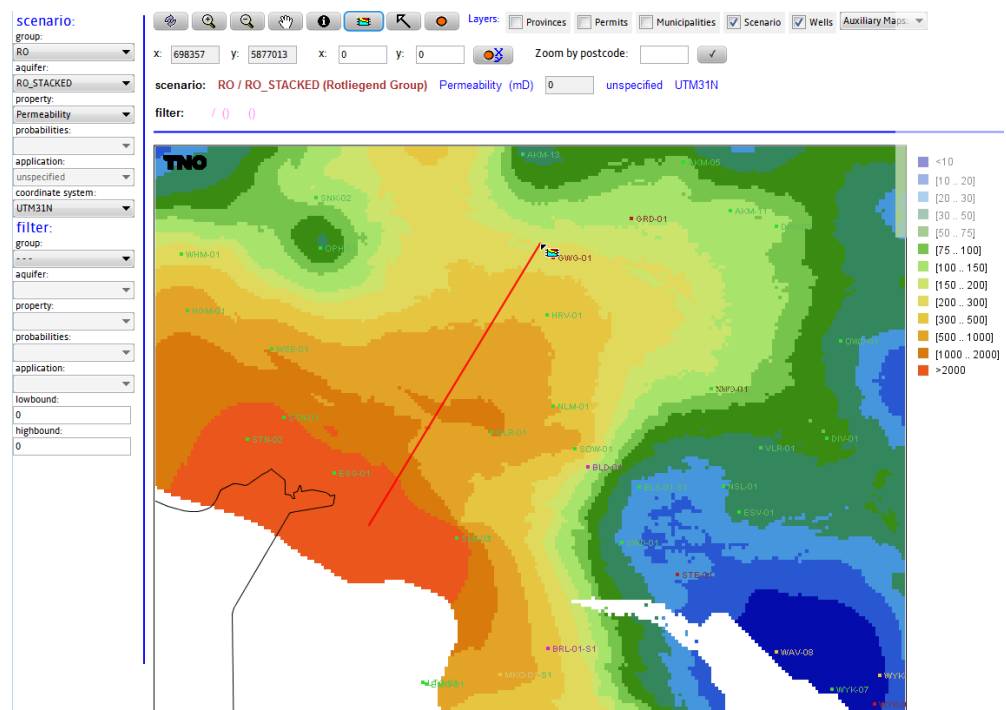


Figure 12 by dragging a line across the display after the cross-section mode is activated a new window will appear automatically showing the subsurface (Figure 13).

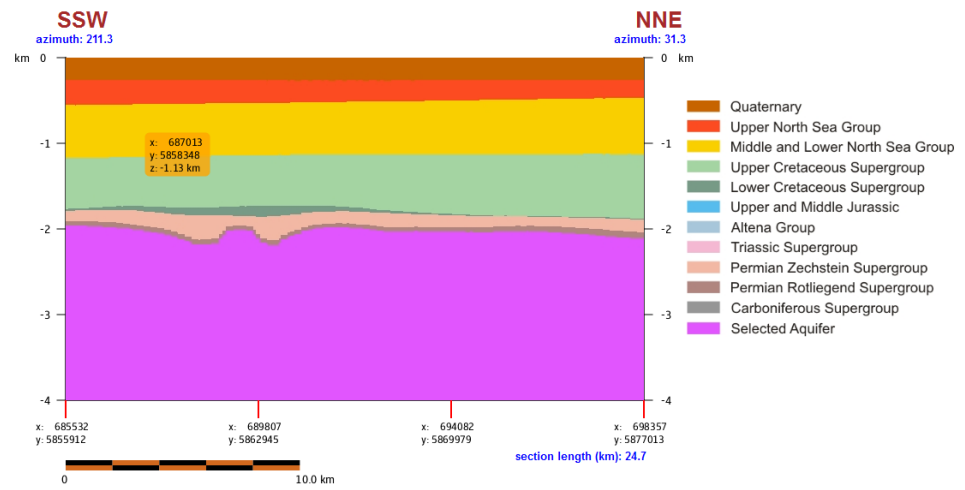



Figure 13 a cross section will pop up after the mouse button is released. To the right of the cross section a legend shows the geological groups. Marked in purple the selected aquifer is highlighted.

3.2.8 Site specific information [, , , 798.0 , x: y:]

ThermoGIS has several options to get informed about the property values shown on the display. For a global overview the user can use the legend on the right side of the display to obtain a general impression by looking up the color and its corresponding value range.

For more site specific information the user has two options to obtain specific values from a certain location. By pressing  and moving the cursor across the display the specific number of the selected property will be displayed in the text-box (798.0) on the information bar (Figure 14). From the x: y: text boxes you can read out the x,y-coordinates of the cursor on the map display.

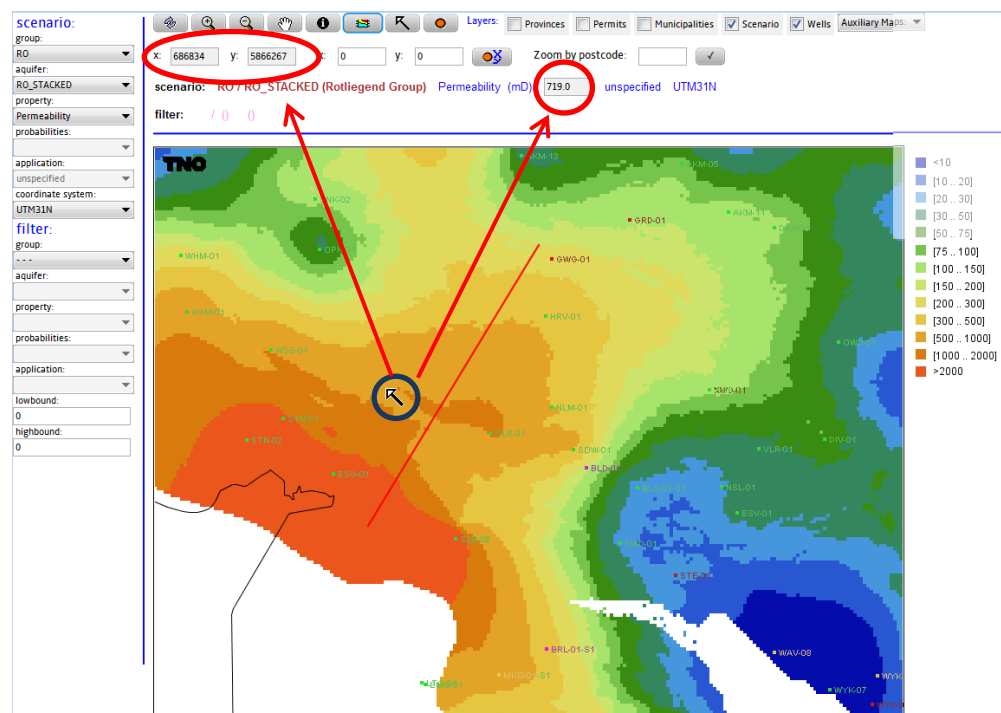






Figure 14 while moving the cursor across the display the values for the selected property will be indicated in the information box of the information panel.

Another option is to use the location point-mode that can be activated by pressing . The cursor will change in  when moved across the display. The location indicator can be fixed on the map by clicking the left mouse button on a location of interest. To remove the indicator, click the left mouse button.

In case the user knows the x,y-coordinates of a location of interest it is possible to enter these coordinates in the text boxes in the upper right corner of ThermoGIS. After clicking on  a location point will appear on the display.

When the location point is placed, an info tag will pop up showing all parameters from that specific location as soon as the mouse cursor  is placed on the location point (Figure 15).

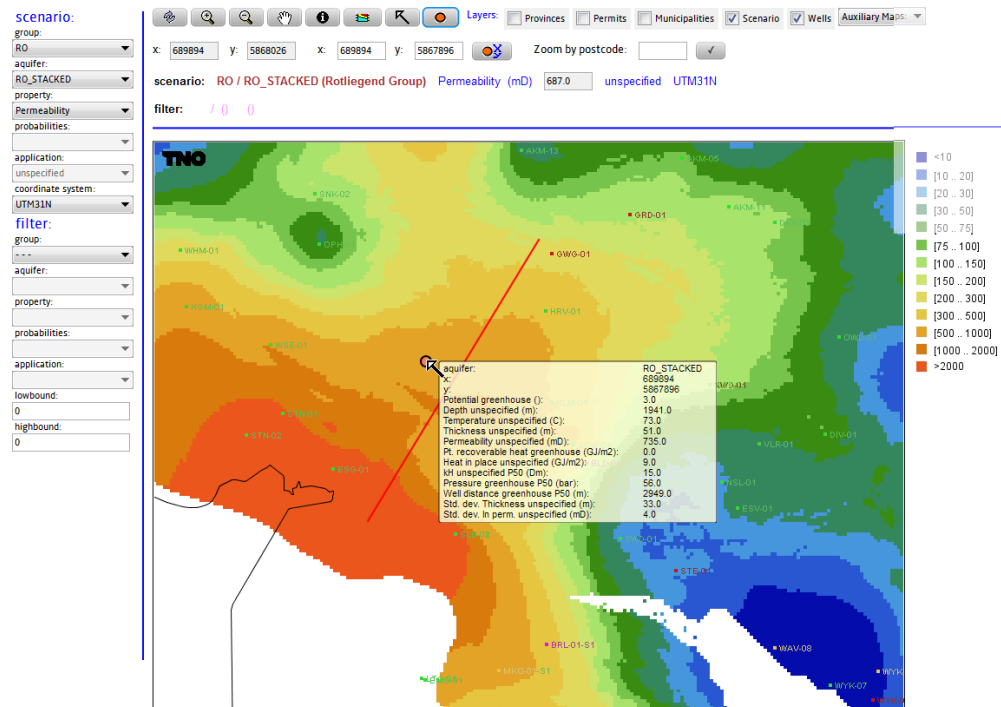





Figure 15 using the location button and moving the cursor on the selected position will give an info box showing the aquifer parameters at that location.

3.2.9 Doublet calculator

When the location indicator is clicked ones a doublet calculator window will activate (Figure 16). Doublet calculator is a program that allows the user to perform a techno-economic performance assessment for the selected location. For the computation of the performance doublet calculator collects all relevant parameters from the geological maps in ThermoGIS at the specified indicator location. Detailed information about doublet calculator can be found in the TNO-report (Mijnlieff et al., 2009). An economic supplement can be found in part II of the manual.

When  in the scenario panel is selected it is not possible to start doublet calculator by pressing on the location point. In this case the location indicator is colored red () instead of orange (). This is only possible after a group and aquifer is selected in the scenario selection combo boxes and the data is retrieved.

number of simulation runs (-) 1000

Calculate !

Open Scenario

Save Scenario

Exit Program

Geotechnical input

A) Aquifer properties

Property	min	median	max	Property	value
aquifer permeability (mD)	3.0	735.0	10000.0	aquifer kh/kv ratio (-)	1.0
aquifer net to gross (-)	0.99	1.0	1.01	surface temperature (°C)	10.0
aquifer gross thickness (m)	0.1	51.0	129.0	geothermal gradient (°C/m)	0.0319
aquifer top at producer (m TVD)	1747.0	1941	2135.0	mid aquifer temperature producer (°C)	0.0
aquifer top at injector (m TVD)	1747.0	1941	2135.0	[aquifer pressure at producer (bar)]	0.0
aquifer water salinity (ppm)	80357.4	89286.0	98214.6	[aquifer pressure at injector (bar)]	0.0

B) Doublet and pump properties

Property	value
exit temperature heat exchanger (°C)	30.0
distance wells at aquifer level (m)	2949.0234
pump system efficiency (-)	0.6
production pump depth (m)	300.0
pump pressure difference (bar)	55.955135

C) Well properties

segment length (m) 50

Producer				
outer diameter producer (inch)	8.0			
skin producer (-)	2.0			
penetration angle producer (deg)	0.0			
skin due to penetration angle p (-)	0.0			
Segment	tubing segment sections p (m AH)	tubing segment depth p (m TVD)	tubing inner diameter p (inch)	tubing roughness p (milli-inch)
1	2632.5576	1941	7.0	1.38
2				
3				
4				
5				
6				
7				
8				

Injector				
outer diameter injector (inch)	8.0			
skin injector (-)	0.5			
penetration angle injector (deg)	0.0			
skin due to penetration angle i (-)	0.0			
Segment	tubing segment sections i (m AH)	tubing segment depth i (m TVD)	tubing inner diameter i (inch)	tubing roughness i (milli-inch)
1	2632.5576	1941	7.0	1.38
2				
3				
4				
5				
6				
7				
8				

[] optional

Economic input (SDE+)



A) Lifetime & maintenance

Property	value	Property	value
economic lifetime (yr)	30.0	heat exchanger season factor (-)	0.6
pump replacement (yr)	5.0	load hours (hr/year)	5256.0

B) Investment & operational costs

Property	min	median	max
electricity price to buy (cts/kWh)	7.9	8.0	8.1

Property	value	Property	value
capex for heat exchanger (M€/MWth)	0.1	fixed OPEX rate (-)	0.02
CAPEX pump (M€)	0.5	variable OPEX (€/GJ)	0.0
well cost scaling (-)	1.2	pump workover costs (M€)	0.25


C) Economic properties


Property	value	Property	value
tax rate (%)	25.5	debt percentage (%)	80.0
inflation (%)	2.0	required return on equity (%)	15.0
interest on the loan (%)	5.0		

Figure 16 With the Doublet calculator a techno-economic performance assessment can be performed. The calculator will launch after the location indicator on the map is clicked on once.

3.2.10 Filtering [filter: , lowbound: 0 , highbound: 0]

From the **filter:** panel on the left side it is possible to highlight areas on the scenario map. In principal the aquifer associated filter is identical to the workflow of the scenario selection combo boxes as described previously. It can be activated by selecting a group from the group-combo box in **filter:**. Analogue to the procedure described for the scenario combo boxes one can select and load an aquifer, properties, application type etc.

You can defined a minimum and a maximum value and enter these in in the text boxes lowbound: highbound: 0 0 . After pressing , the filter will blend the scenario map in pinkish colors.

For instance, select RO and RO_stacked from the group and aquifer combo box in the filter panel respectively (Figure 17). Enter 600 as lowbound number and 1000 in the highbound text box. Press  again. After retrieving the data the area is highlighted in pink. This is the area where the RO aquifer has a permeability between 600 mD and 1000 mD (Figure 18).

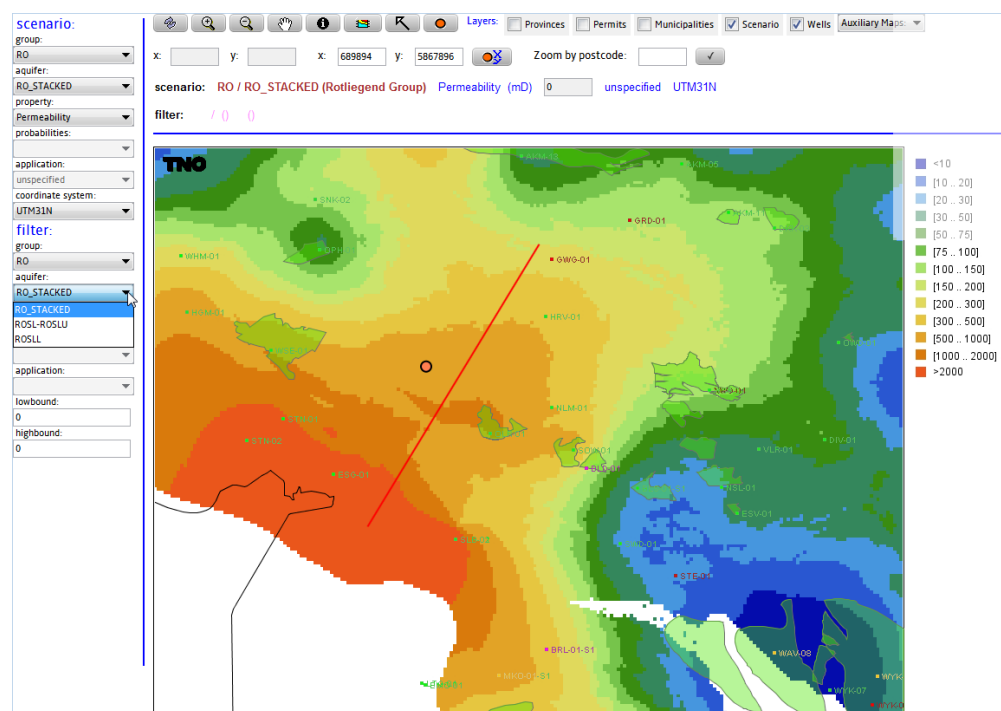


Figure 17 To exclude or highlight areas within certain boundaries, respectively selected RO in de Group combo box and RO_stacked in de aquifer Combo box. Notice that in this figure the gasfields in this area are indicated. These have been selected in the auxiliary maps.

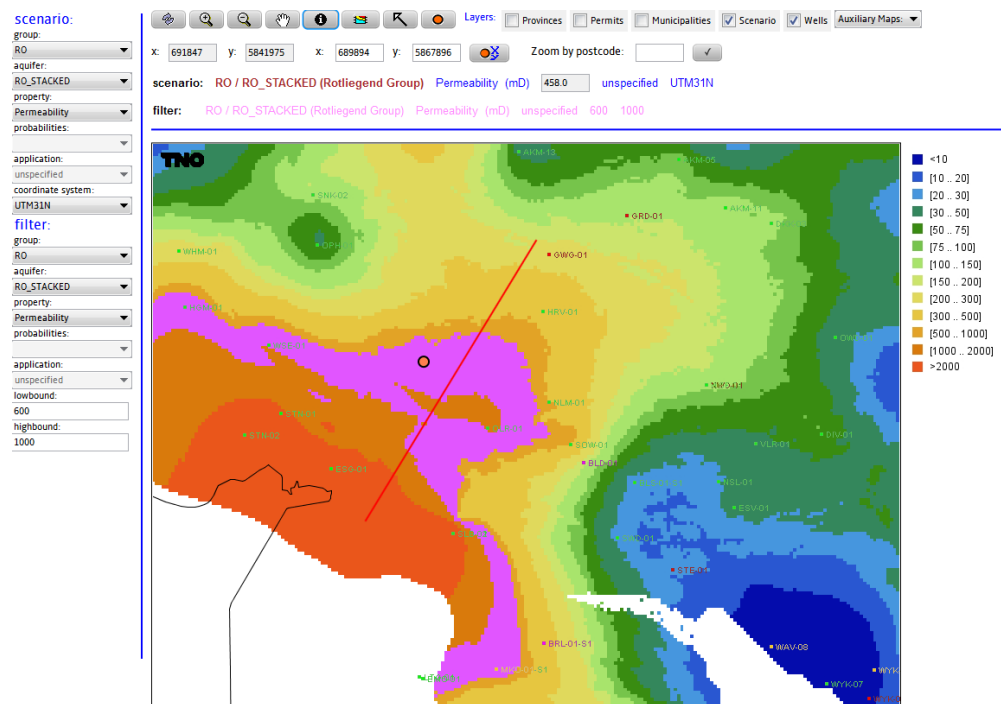


Figure 18 display shows the area of the RO aquifer with the permeability is 600-1000mD.